INVESTIGATIONS IN THE HYGIENE OF READING

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INVESTIGATIONS IN THE HYGIENE OF READING

INTRODUCTION

Educational science is revealing more and more the importance of the Art of Reading in all fields of mental activity. The average man now reads widely both for pleasure and information, while progress in all the professions depends directly upon it. This has had its effect upon the schools and to-day reading is the most fundamental subject in the elementary school curriculum, for the child must now be trained to gather information rather than to memorize that which has already been prepared for his assimilation. Hence, reading has become the most important criterion in determining whether or not a child is prepared to advance. It is therefore, important that we should know just what are the most effective ways of preparing the printed page so that the reader may obtain the ideas presented there with the least expenditure of time and effort. Considering this, it seems little short of amazing that more has not been done by way of giving final and definite answers to the problems involved in

the hygiene of reading, first, that vision may not be impaired and, second, that efficiency may be increased. Reading is not a natural activity; it is a highly artificial accompaniment of civilization. Hence, every advantage which modern science can devise should be brought into play in minimizing the sheer mechanical effort which is made in the process. Yet, little has been done by way of subjecting these considerations to definite experimentation.

This study is limited to the first four grades. The reasons for this limitation are: first, there is more variation in the typography of elementary readers in these than in readers of the upper grades and, second, the size and importance of the problem makes it advisable that we limit ourselves to a small portion of the field.

It is impossible to express other than impersonally the writer's obligation to the many friends whose kindness has aided him in this study. It is possible to pay only inadequately the debt of gratitude due Professor Elmer E. Jones, Director of the School of Education, Northwestern University, also Professor L. W. Webb and Professor J. A. Clement, for the encouragement and constructive criticism given. It is a pleasure to acknowledge the thanks due Professor W. S. Gray of the University of Chicago and Professor C. T. Gray of the University of Texas for early inspiration in this field. Special thanks are due Ernest E. Cole, First Assistant Superintendent of Schools of the City

of Chicago, J. R. Harper, Superintendent of Schools, Wilmette, Illinois and J. M. Scudder, Superintendent of Schools of Huntington, Indiana for their cooperation in the matter of providing opportunity for experimentation.

CHAPTER I

HISTORICAL REVIEW

EXPERIMENTATIONS

The first interest in the question of how we see, apart from philosophical considerations of it,[1] was, as far as the writer can discover that of Plateau,[2] who in about the year 1835 said that it took a certain length of time for an impression to be produced by light. Flick later, by some experimentation, confirmed the opinion of Plateau.[3] Bruecke found this time to be .119s decreasing in arithmetical progression as the intensity of light increased in geometrical progression.[4]

The importance of all this early work lies chiefly in the fact that it pointed the way to further investigations. The motive which prompted it was, as seems to be the case in nearly all early research which ultimately proves to have a practical bearing, not utilitarian but rather the desire to know for the sake of understanding. From

[1] The question as to how an object can so communicate with the eye as to produce the phenomenon of sight is as old as philosophy. It was held by early thinkers that the object gave off a very thin film which maintained its form as it passed into the eye.

[2] Brain Vol. VIII, pp. 295.

[3] Ibid.

[4] Ibid.

the work of the above men there resulted two lines of interest. One is but a continuation of the past interest and has resulted in the information that we now have with respect to the activity of the eyes during the reading process. The other line of interest has had a utilitarian motive and has resulted in the little scientifically valid information which we now have regarding the hygiene of reading.

The first to write and experiment with the problems of the hygiene of reading definitely in mind was Doctor Emele Javal whose work was reported in "Essaies sur la physiologie de la lecture" 1878–9,[1] Javal attempted to work out the order of legibility in the letters, which he tested by the distance at which they could be read. In 1881 Adolph Weber, a German investigator,[2] tested the time occupied in reading different types and found that the letters greater in size than 2 mm. retarded the speed of reading. He set 1.5 mm. as the minimum. He, also, advanced the theory, based upon his research, that lines 14 to 15 cm. in length could be read more readily than those shorter or longer.

Weber's work was followed in the year 1883 by the writings of Herman Cohn, whose book, "The Hygiene of the Eye" did much to popularize the question of more consideration for the eyes of school children.[3]

[1] Pedagogical Seminary 1892, pp. 49–51.
[2] Pedagogical Seminary 1892, pp. 49.
[3] Cohn, The Hygiene of the Eye.

The book undoubtedly stimulated further research on the more practical side of the question of the hygiene of reading. Cohn believed that 100 mm. (4 inches) was the maximum length of line advisable and 90 mm. (3.6 inches) the best length of line where the small letters were 1.5 mm. in height. If larger letters were used Cohn believed a line of 110 mm. possible.

With respect to the hygiene of reading Cattell[1] distinguished four operations the time taken by each of which might furnish subject matter for an experiment; (1) The time light must work upon the retina in order that a sensation may be excited. (2) The time light must work upon the retina in order that the maximum intensity of sensation may be brought about. (3) The time necessary for light to be changed into a nervous impulse. (4) The time taken up in the nerve and brain before the light is seen. In 1886 Cattell investigated the last two operations by means of an instrument, which he called a gravity chronometer.[2] This instrument consisted of a heavy soft-iron screen set in two brass columns. The screen was held in position by means of a magnet which at the breaking of the current allowed the screen to fall. A slit in the screen exposed for a small fraction of a second the character to be read. The screen was covered with smoked paper and a tuning fork allowed to write upon

[1] Brain Vol. VIII, pp. 295–312.
[2] Ibid.

it as it fell. By this means the time of exposure of the object could be determined. He found that the time a colored light must work upon the retina was different for the several colors, the retina being most sensitive to orange and least sensitive to violet. He also found that in the case of one color following another the time necessary for the recognition of the second was increased from about two and one-half to fifteen times its usual length.

With respect to the effect of the intensity of light upon the time of recognition Cattell makes the following statement: "The portion of the curve I have investigated follows the formula,

$$t = c \log i (+c')$$

in which t is the necessary time and i the intensity of the light; that is, the time colored light must work on the retina in order that it may be seen, increases in arithmetical progression, as the intensity of the light decreases in geometrical progression."

Cattell used the same method as was used for colors in determining the time the light reflected from a letter or a word must work upon the retina in order that it may be distinguished.[1] He concludes as follows: "As I have already stated, not only are some types harder to see than others but different letters in the same alphabet are not equally legible . . . Out of one

[1] Brain Vol. VIII, pp. 295–312.

hundred trials, d was read correctly 87 times, s only 28 times. The order of distinctness for the small letters was as follows: d k m q h b p w u l j t v z r o f n a x y e i g c s . . . As in the case of capital letters, some letters are hard to see (especially s, g, c, and x) owing to their form; others are misread, because there are certain pairs and groups in which the letters are similar. A group of this sort is made up of the slim letters i j l f t, which are constantly mistaken the one for the other."

Doctor E. C. Sanford[1] tested legibility of letters using as a criterion of legibility, first the distance test and later the time test. For accurate measurement of the distance a wooden rail 3.4 m. long was placed before the subject slanting down from the chin at an angle of about fourteen degrees. A movable disk of cardboard was placed upon a sliding car which operated on the rail. Before the disk was placed a black cardboard screen pierced by a square hole of two cm. Hence, by rotating the disk any letter could be shown. A millimeter scale pasted along the top of the rail marked the distance. Sanford in the distance tests used the clear sky for illumination. Legibility for distance was measured in two ways.

In the first the disk was set in a given position and all the letters exposed two or more times. The distance

[1] Sanford, E. C. The Relative Legibility of Small Letters of the Alphabet. American Journal of Psychology, Vol. I, 1887–8.

was then increased and the letters again exposed two or more times. This was continued until none of the letters could be recognized. The distances were then correspondingly decreased till all the letters could be read. In case a subject was not certain of a letter he announced what he thought the letter to be, giving the possible letters in order of probability, unless all seemed to be equally probable. Sanford says, "This method gives us the order of legibility as shown by the number of times each letter was rightly or wrongly named, all distances being taken together, and at the same time the letters with which each is most confusable when the confusion is caused by distance."

The second method was used as a check upon the first and as a means of determining more accurately the distance at which letters are just legible. In this method the letter was placed at a point just beyond recognition and the car moved upward until the letter could be correctly announced. Two points were generally recorded, the one at which the subject thought he recognized the letter and the other at which he was certain.

For the time tests the letters were set in a dark box and the length of their exposure controlled by the length of an artificial illumination. This was in turn controlled by overlapping disks driven by a pendulum. The shaft upon which the pendulum swung was set in bearings that allowed the pendulum to turn completely

around, over and over. The pendulum was of sufficient weight to operate a cogwheel of 144 teeth which in turn operated two cogwheels of twelve teeth each. Hence, for every revolution of the large cogwheel the little wheels would make twelve revolutions. These small cogwheels operated two disks which moved in opposite directions. Notches in the disks allowed an artificial light to pass through as they passed each other. Hence, every complete turn of the pendulum would result in twelve flashes of light, all but one of which were shut off by another disk behind these two. A notch in its edge allowed the light to pass during that portion of the circuit of the pendulun in which the shortest of the notches of the large disks occurred, and cut off at other times. The size of the notch necessary to let through light for a given fraction of a second was determined by means of a tuning fork, which was allowed to write upon a smoked disk during one revolution of the pendulum.

The following are the orders of legibility as determined by the three methods:

Distance Test
First Method—Standard, Snellen optotype
m w f p q r j v k b y h d g x a i l u s t n e c o z
Distance Test
Second Method—Standard, Snellen optotype
Subject H,
w m j f v y q p d h b r x l g u k n z o a t c s e i

Subject M,
m w y q p h d k b v x j u n r l f g t c o s a z i e
Subject J,
y m f j w v g q p b x r d h n t k i u o z l a s c e
Time Test
m w d q v y j p k f b l i g h r x t o u a n e s c z

Sanford points out that by a strange bit of perversity several of the worst letters are those most frequently used. This is most strikingly true of the letter e. The group most prone to confusion was found to be f j i l t. Small s is more likely to be confused with these letters than with a or z. Cattell would use a different character for 1 and do away with the dot over the i.[1] The results of this experiment are briefly summed up in the words of Sanford: "With most of the letters breadth is rather of more advantage, other things being equal, than length for it gives some visibility to their internal spaces; and Doctor Javal is undoubtedly right in preferring short broad letters to long narrow ones." The rounded effects of letters like s proves confusing; while the angular effects of letters like z made them more easily distinguishable.

In 1904 and 1905 Doctor W. F. Dearborn, along with other psychological studies on reading investigated the effect of line arrangement upon fixation pauses and the effect of length of text line in the matter of establishing desirable motor habits with respect to eye-movements.

[1] Brain Vol. III, pp. 295–312.

In this study the eye-movements were photographed.[1] Dearborn concludes as follows: "These motor habits are most easily acquired in the shorter lines and aid materially the rapidity of reading. Length of text lines is mainly important in its effect upon the formation of motor habits. The rate of reading depends upon the ease with which a regular rythmical movement is established. Uniformity of line length aids, also, in establishing rhythmical eye-movements. Lines should be from 75 to 85 mm. in length."

In 1910 Floyed Carlton Dockeray[2] working in the Psychological Laboratory of the University of Michigan studied the relative legibility of letters of the alphabet by means of a Cattell fall chronoscope, which was placed between the source of light and an aperture leading to the letters. The findings of this study, however, did not well agree with those of Sanford. For example, the letter n, which appears near the first in Sanford's results, is found to be nearly the poorest

[1] The technique of registering the movements of the eyes had been evolved earlier by Doctor Huey, at Clark University and Professor Delabarre at Harvard University, who at the suggestion of Doctor Lough resorted to the use of a plaster-of-Paris cup, which was attached to the cornea of the eye. The moist cornea caused the thin cup to adhere tightly. The reader read through a round hole. A light tabular lever of celloidin and glass connected the cup to a pointer, which registered the movements upon the smoked surface of a moving drum cylinder. Professor Dodge later succeeded in photographing a beam of light reflected from the cornea upon a moving plate. This gave a true record of the eye-movements when unhampered by a weight as in the case of Dr. Huey's method.

[2] Journal of Educational Psychology, Vol. I, 1910.

in the series of Dockeray. There is agreement in that both found broad letters to be the most easily read; while the tall thin letters were the least satisfactory.

The next investigation was that of Barbara Elizabeth Roethlein at Clark University in 1911.[1] Doctor Roethlein studied the relative legibility of some fifty faces of type, comprising some thirty ordinary faces together with such variants as italics, bold, condensed, expanded and various combinations of these. In her earlier experiments the time method was employed but this was later discarded for a contrivance by means of which the letters to be read were placed at varying distances.

All the readings were made in a semi-darkened room in order that the artificial illumination upon the sheet of letters might be controlled and kept constant throughout. The experimental procedure was as follows: After the observer had become adapted to the illumination of the room, a sheet of letters was placed in position in the carriage and a series of readings begun with the carriage at the further end of the bench. The observer had been instructed to read the letters at a uniform rate, substituting "blank" for the name of any letter which was not easily decipherable. This precaution was made to prevent the observer from giving an undue amount of attention to any one letter of the series at the expense of the other letters, i. e. to prevent him from puzzling

[1] American Journal of Psychology Vol. XXIII, 1912, 1–36.

longer over one member of the series than over any other member. After he had thus attempted to read through a complete list of letters, the carriage was moved to a point twenty centimeters nearer his eye than the initial setting; and he made a second attempt to read through the letters. In the first and alternate readings of each series he began at the upper left-hand corner of the sheet and proceeded from left to right along each line taking the lines in order from the top downward. In the second and alternate readings he began at the lower right-hand corner of the sheet and proceeded from right to left, and from below upward. This procedure was continued, the carriage being advanced step by step, until every letter upon the sheet had been identified.

The capital letters which proved to be the most distinguishable were the Jensen Old Style. The American Typewriter letters were the most difficult to distinguish. The Jensen Old Style is a broad letter with thin lines. Hence, this result is so far in keeping with the findings of Dockeray, Sanford, and Javal.[1] The optimal heaviness of face seems to Roethlein to lie in a mean between the bold faces and such light faces as Scotch Roman and Cushing Monotype. In the above investigation the letters were tested, first, in isolation and then in groups, but not in word arrangements.

[1] Journal of Educational Psychology Vol. I, 1910.
American Journal of Psychology Vol. I, 1887–8.

Dr. A. R. Gilliland in a study called "Experimental Studies of the Effect on Reading of Changes in Certain Sensory Factors" studied the effect of changes in size and form of type. Two methods of study were used. First a large number of subjects read a series of paragraphs printed in different sizes of type. The rate of reading was noted. A more analytical study followed in which photographs of eye-movements were taken while reading. The following sizes of type were read: 3, 4, 6, 9, 12, 24, 36, 54, and 90 points. As all type sizes were photographic enlargements or reductions of twelve-point type with a 20 em line the line lengths varied with the size of type used. Children in the third, fourth, and fifth grades and adults acted as subjects. Gilliland's general conclusion is to the effect that size of type is not an important factor in the reading process so long as the size of type is not extreme either in the direction of small or large type.

The present writer feels that Dr. Gilliland in interpreting his data did not give sufficient consideration to the fact that a small difference in reading difficulty which may show up when reading short specimens may become a very great difference in reading difficulty when the paragraph is extended to the size of a book.

The Committee on the Standardization of School text books, which was composed of the following members, William H. Burnham, Willard S. Small, and Myles Standish, in its report at the Fifth Annual

Congress of the American School Hygiene Association set up the following norms as regards text books:[1]

(a) The paper should be unglazed, free from shine, and opaque.

(b) The eye moves by a succession of movements and stops and makes a long backward sweep to the beginning of the next line.
Fatigue is markedly increased by the difficulty of the backward movements and in locating the beginning of the next line, if the line is too long. The maximum of safety is 90 mm. and 60 mm. to 80 mm. is better.

(c) The margin should be sufficient so that the eye, in the backward movement does not swing off the paper; and the inner margin should be wide enough so that the inner end of the line is not obscured by the curvature of the paper.

(d) The sizes of the type should be as follows:—1. Adult standard—(i) The height of the small letters should be 1.5 mm. (ii) The width of the vertical stroke should be .25 mm. (iii) The space within the letters should be .5 mm. (iv) The space between the letters should be .50 to .75 mm. (v) The space between the words should be 2 mm. (vi) The leading should be 2.5 mm.
2. Standards for children are as follows:
A. First grade—(i) The height of the small letters should be at least 2.6 mm. with the other dimensions in proportion. (ii) The width of the vertical stroke should be from .4 mm. to .5 mm. (iii) The space within the letters should be from .8 mm. to .9 mm. (iv) The space between the letters should be about 1 mm. (v) The space between the words should be about 3 mm. (vi) The leading should be 4 mm. to 4.5 mm.
B. For the second and third year the standard may be reduced slightly, but the letters should not be less than 2 mm. in height, and the leading should be 4 mm.
C. For the fourth year height and leading should not be less than 1.6 mm. and 3 mm., respectively. It would be better to retain the standard of the fourth year through the sixth year.

[1] Report of the Committee on the Standardization of School Text-books, Proceedings of the American School Hygiene Association—Fifth Annual Congress, 1911.

The latest material on the hygiene of reading that has come to the attention of the writer is the report of a committee of the British Association for the Advancement of Science on the influence of school books upon eyesight. The following typographical table gives the standards recommended with respect to size of type, leading, and length of line for each of the school years:

TABLE I.—STANDARD TYPOGRAPHICAL TABLE

Age of reader	Minimum height of faces of short letters	Minimum length of alphabet of small letters	Minimum inter-linear space	Maximum no. of lines per vertical 100 mm.—4 in.	Maximum length of measure of line
Under 7 yrs.....	3.5 mm.	96 mm.	6.5 mm.	10	
7 to 8 yrs.....	2.5 mm.	72 mm.	6.4 mm.	15	100 mm. or 4 in.
8 to 9 yrs.....	2.0 mm.	55 mm.	2.9 mm.	20	93 mm.
9 to 12 yrs.....	1.8 mm.	50 mm.	2.4 mm.	22	93 mm.
Over 12 yrs.....	1.58 mm.	47 mm.	2.2 mm.	24	93 mm.

ANALYSIS OF TEXT-BOOKS

Edward R. Shaw made an analysis of the type found in four primers with the following results:

TABLE II.—SIZE OF TYPE AND LEADING FOUND IN FOUR PRIMERS

	Type mm.	Leading mm.
Primer A Part I.....	3.5	7.0
Primer A Part II.....	2.5	5.7
Primer B.....	3.0	6.0
Primer C.....	3.5	7.5
Primer D.....	3.0	5.0

The writer made a study of three hundred and twelve elementary school readers published from 1860 to the present time for the purpose of determining what has been the trend of their typography.[1] The books were grouped as follows: those published before 1890, those published between 1890 and 1900, those published between 1900 and 1910, and those published between 1910 and the present time.[2] The study of the books published between 1910 and the present time furnish a good sample of that which is at present being read by the American school children.[3]

[1] The readers studied were those found in the library of the School of Education of the University of Chicago.

[2] The writer determined the initial publication of a book by the copyright. Books copyrighted, say between 1890 and 1900, were considered as belonging to the publications of that decade though they may have been used widely during the following decade.

[3] The above study was published in School and Society November 5, 1921.

TABLE III.—HEIGHT OF SMALL LETTERS

	Before 1890	1890–1900	1900–10	1910 to present
First grade				
No. books studied	35	34	24	64
Median (mm.)	2.53	2.54	2.46	2.50
S. D.	.63	.59	.29	.33
Second grade				
No. books studied	13	5	10	20
Median (mm.)	2.09	2.19	2.18	2.32
S. D.	.29	.20	.20	.22
Third grade				
No. books studied	2	2	4	6
Median (mm.)	1.63	2.00	2.00	2.00
S. D.	.13	.00	.00	.24
Fourth grade				
No. books studied	6	4	9	14
Median	1.63	1.75	1.75	1.75
S. D.	.13	.00	.20	.26
Fifth grade				
No. books studied	8	2	4	10
Median (mm.)	1.50	1.75	1.75	1.75
S. D.	.00	.00	.00	.11
Sixth grade				
No. books studied	3	1	4	6
Median (mm.)	1.50	1.50	1.75	1.75
S. D.	.30	.00	.00	.15

In general there was an increase in the size of type used in school text-books between the years 1890 and 1900. The first grade however, is an exception, for here the size of type has remained about constant. That there was no evidence of increase in the size of the print found in sixth grade readers may have been due to the fact that only one sixth grade reader of this period was examined.

Another interesting consideration is the fact that the type becomes smaller as we go up the grades from the first to the fourth but at this grade a minimum has been established which remains constant through the fourth, fifth, and sixth. There has been a tendency to gradually increase the size of type used in the second grade.

TABLE IV.—LENGTH OF LINE

	Before 1890	1890–1900	1900–10	1910 to present
First grade				
No. books studied	32	30	32	63
Median (mm.)	89.00	98.00	101.41	101.00
S. D	9.60	8.10	10.50	10.20
Second grade				
No. books studied	12	5	7	16
Median (mm.)	89.00	106.00	102.00	102.00
S. D	6.32	3.32	5.20	6.30
Third grade				
No. books studied	2	2	4	5
Median (mm.)	84.00	94.00	97.00	102.00
S. D	5.00	.00	8.30	8.72
Fourth grade				
No. books studied	6	4	9	14
Median (mm.)	89.00	93.00	103.00	101.00
S. D	4.79	7.07	10.50	6.24
Fifth grade				
No. Books Studied	8	2	4	10
Median (mm.)	89.00	96.00	102.00	97.50
S. D	4.79	.00	4.36	7.07
Sixth grade				
No. books studied	3	1	4	6
Median (mm.)	88.00	94.00	97.00	101.00
S. D	4.79	.00	5.00	4.24

The change that took place during the years 1890 to 1900 is more striking in the case of the length of line than in the size of type for, considering all the readers of any of the first six grades for any decade, there is no exception to the increase. The greatest increase in line length at this time took place in the first two grades. In the case of the third, fourth, fifth, and sixth grades a smaller increase in the length of line was made with an additional increase during the years 1900 to 1910. In the books published since 1910 the length of line has been about the same for the first six grades, the median length being 101 millimeters.

TABLE V.—LEADING

	Before 1890	1890–99	1900–10	1910 to present
First grade				
No. books studied	35	34	24	64
Median (mm.)	1.90	2.41	2.78	3.12
S. D	1.79	2.50	1.17	1.57
Second grade				
No. books studied	13	5	10	20
Median (mm.)	1.13	2.19	2.25	2.63
S. D	.28	.18	.49	.67
Third grade				
No. books studied	2	2	4	6
Median (mm.)	1.25	1.75	2.00	2.10
S. D	.50	.00	.11	.37
Fourth grade				
No books studied	6	4	9	14
Median (mm.)	1	1.63	1.75	1.75
S. D	.14	.27	.26	.59
Fifth grade				
No. books studied	8	2	4	10
Median (mm.)	.87	1.25	1.56	1.25
S. D	.28	.13	.11	.32
Sixth grade				
No. books studied	3	1	4	6
Median (mm.)	1.00	1.50	1.25	1.50
S. D	.12	.00	.31	.88

The above table shows that leading was materially increased in all the first six grades during the years 1890 to 1900. In general a further but lesser increase was made during the years 1900 to 1910. A further increase was made in the leading of books for the first three grades since 1910. Considering the question of leading from the standpoint of the grades involved, there has

been a steady decrease in the amount of leading used as we go up the grades from the first to the fifth. From the table it would look as though there was a tendency to increase the leading used above the fifth grade, but this is, no doubt, due to the small number of books which could be obtained in the upper grades for measuring.

TABLE VI.—REGULARITY OF MARGINS
First Grade

	Before 1890	1890–99	1900–10	1910 to present
No. books studied	25	30	32	64
Both margins regular	29%	27%	13%	13%
Both margins irregular	54%	46%	43.5%	56%
Left margin regular only	17%	27%	43.5%	31%

It was sometimes difficult to classify a book with respect to marginal regularity because the margins were regular on some pages and irregular on others. In deciding upon a book of this kind the writer determined which type of margin was most used and classified the book accordingly.

Books with both right and left margins irregular were by far the most common as is shown by the above table. There was a tendency from 1890 to 1910 to make the left margin regular leaving the right irregular. From 1910 to the present time, however, the tendency has been to make both margins irregular.

CHAPTER II

STATEMENT OF PROBLEM AND DISCUSSION OF METHOD

STATEMENT OF PROBLEM

The questions the writer wishes to answer with respect to the hygiene of reading are as follows:

1. What size of type is most readable in each of the first four grades for children of normal age?[1]

[1] The following ages were considered normal in each of the first four grades: first grade—from the beginning of the sixth to the beginning of the seventh year, second grade—from the beginning of the seventh year to the beginning of the eighth year, third grade—from the beginning of the eighth year to the beginning of the ninth year, fourth year—from the beginning of the ninth year to the beginning of the tenth year. Dr. Leonard P. Ayres in a pamphlet entitled "The Relation between Entering Age and Subsequent Progress among Children" shows from a study of 13,867 children representing twenty-nine cities, that more children enter the first grade at six years of age than at any other age. His table also shows that the most common rate of progress is one grade per year. Hence, it follows that more children will be found in the first, second, third and fourth grades at ages six, seven, eight, and nine years than at any other ages. A study of the ages of the children who were used in this investigation showed that the median ages for grades one, two, three, and four were at the time the study was made six years and nine months, seven years and seven months, eight years and nine months, and nine years and nine months respectively. In other words the children were of normal age for the grades represented.

2. How many millimeters of leading are most desirable in each of the first four grades for children of normal age?[1]

3. What length of line is most desirable in each of the first four grades for children of normal age?

4. Is the irregularity of beginning and ending of lines an advantage to first grade children of normal age, i. e. should every line in a paragraph, excepting the first, which is customarily indented, and the last, which may fall short due to lack of material, begin and end so as to form a solid margin, i. e., one with no indentations, or should the right margin be solid and the left irregular, or should the left margin be solid and the right irregular, or should both margins be irregular?

This investigation is limited to the first four grades of the elementary school. The size of type, leading, and line length were studied in all, while the effect of marginal regularity was studied in the first grade only.

DISCUSSION OF METHOD

There are many factors which function in determining the facility with which a given passage is read. Hence, in order to study any one it is necessary to understand

[1] "Leading" is a printers term used to indicate the amount of space between the lines. It derives its name from the fact that in setting type the printer uses thin oblong sheets of lead to separate one line of letters from the next. When leads are not used the print is termed "solid." The letters in solid matter are prevented from touching those of the next line above or below by the shoulder of the type. The shoulder is the block of the type which lies around the letter form.

and control all the others. We may classify them as follows: (a) Those which belong to the print itself such as size of the type, length of line, leading, regularity of the margins, etc. (b) Those which are more truly a part of the reader's environment such as illumination, attitude of the experimentor, position of the reader, constant or sudden noise, etc. (c) Those which affect the subjective attitude of the reader, such as, thoughts which may enter the mind of one while reading, causing states of depression or exhilaration. (d) The amount of learning which precedes the reading, i. e. has it been read before and how often. (e) The amount of reading ability with which the child approaches the task.

As was indicated above, if one is to vary any one of the reading factors so as to study the effect of the variation all the others must be treated so that each will remain constant throughout the study. For example, in determining the size of type most favorable to reading six specimens of varying sizes in which all the other factors listed under (a) were identical, were prepared.

In consideration of the factors under (b) all the testing in any given grade was done in rooms which were quiet and well lighted. Each child read standing, facing so that the light, which was in all cases sunlight, came from behind. The experimentor sat behind and a little to the right or left of the child. In case the child was disturbed during the reading of a specimen by the

entrance of a third person into the room or by fire drill-these disturbances did not occur very frequently—another child of equal reading ability was substituted. In a few instances in which the experimentor could not detect any disturbance on the part of the child no substitution was made. As the experimentor's recognizable attitude toward the child may affect the quality of his reading care was taken to treat all the children alike. When the child entered the room he was greeted by the remark "hello there." Great care was taken that this greeting always be given in a pleasant manner. The next remark on the part of the experimentor was "Stand over here please." The child was then asked his name and his card was taken from the list, the order of his reading noted and the specimens arranged. On handing the child the first specimen the experimentor remarked "I wish you would read this out-loud for me." No remark was made in giving the child the remaining specimens unless he did not seem to understand what was wanted of him. In that event he was told "Read it out-loud." A stopwatch, which was used in timing the reading, was kept at the farthest side of the experimentor from the child so that the ticking of the watch could not be heard by him.

The control of the factors listed under (c) was possible only through the operation of statistical laws, i. e. as more and more cases were involved the chances became greater and greater that the time lost or gained

due to subjective or other outwardly uncontrollable disturbances during the reading of any one specimen would exactly offset a similar loss or gain in the reading of any of the other specimens.

The (d) or the learning factor, was the most difficult to control. If one reads three specimens of the same material printed, say in three sizes of type, the improvement made during the process may be entirely the result of learning or a small amount of it may be due to the fact that specimens two and three are more readable than specimen one. If, on the other hand, the factor of readability is becoming less and less favorable it will cause something to be detracted from what would appear to be the result of learning. Because of the fact that the resultant of the factor of learning was very large while the resultant of the factor of readability was in all cases comparatively small great care had to be taken that the learning factor was completely controlled, i. e. considering the experiment as a whole, that the same amount of learning precede the reading of each specimen. This problem can, perhaps, be best illustrated in the following way; suppose, to continue the above hypothetical assumption, we are studying the comparative readability of three sizes of type. Let L represent the largest, M the intermediate, and S the smallest. Let N, N′, AND N″ represent the reading difficulty offered by the three sizes of type respectively. Let d, d′ and d″ represent the decrease in apparent

reading difficulty which is due to the factor of learning. We may then represent the situation by the following diagram:

L	M	S
N-d	N′-d′	N″-d″

The reading order must be so arranged that the d's become equal. The method employed in equalizing the effects of learning was as follows: Let the large type be called Specimen 1, the median size of type be called Specimen 2, and the smallest size of type Specimen 3. As our method of attack is that of reading each it is evident that if Specimen 1 is in all instances read first followed by Specimens 2 and 3 in order that Specimen 2 will have the advantage of Specimen 1 and that Specimen 3 will in turn have the advantage of Specimen 2 for much learning will take place as the subject reads through each. In order that no specimen should have the advantage indicated above they were arranged so that each was read as a first as many times as it was read as a second and as many times as a second as it was read as a third. This, however, does not, as we shall show, suffice in equalizing the learning factor. This may be best shown by a study of the following diagram.

1	2	3
2	3	1
3	1	2

While the above diagram so distributes the readings that each specimen of type is read in each of the posi-

tions first, second, and third as often as is each of the other specimens, we find that if the specimens are read by three people, one reading in the order of the first column, i. e. 1-2-3, a second in the order of the second column, the third in the order of the third column, Specimen 3 will be read twice and Specimen 2 once in advance of Specimen 1, Specimen 1 will be read twice and Specimen 3 once in advance of Specimen 2, and Specimen 2 will be read twice and Specimen 1 once in advance of Specimen 3. The following diagram will represent the situation in a more simple manner.

Specimens	3	3	2 in advance of Specimen 1
Specimens	3	1	1 in advance of Specimen 2
Specimens	2	2	1 in advance of Specimen 3

Let us compare the total opportunities for learning that have preceded the reading of Specimens 1 and 2. In each case Specimen 3 has been read. That leaves one reading of Specimen 3 and one reading of specimen 2 to precede the reading of Specimen 1 as against two readings of Specimen 1 to precede the reading of Specimen 2. Now assume that Specimen 1 is more easily read than Specimen 2 or Specimen 3, then Specimen 2 has the advantage over Specimen 1 because the reader has had more of an opportunity to have read the material well before coming to it. Hence, in the above arrangement of the reading material the learning effect is not completely neutralized.

To do this, however, it is only necessary to group the numbers in the reverse order and use this as often as the above reading order. The following will then represent the orders of reading:

1	2	3		3	2	1
2	3	1	and	2	1	3
3	1	2		1	3	2

We now not only have each specimen read an equal number of times as a first, as a second, and as a third but the reading of each specimen is preceded by an equal number of readings of the other two specimens.

Continuing the above assumption that Specimen 1 is more easily read than Specimen 2, then Specimen 2 will have the advantage of Specimen 1 in that three readings of Specimen 2 precede the reading of Specimen 1, while three readings of Specimen 1 precede the reading of Specimen 2 as is shown in the following diagram:

Specimens 3 3 3 2 2 2 read in advance of Specimen 1
Specimens 3 3 3 1 1 1 read in advance of Specimen 2
Specimens 2 2 2 1 1 1 read in advance of Specimen 3

In other words it is impossible completely to neutralize the learning factor, i. e. so to arrange the reading of the specimens that, considering an entire experiment, each will have been preceded by an equal amount of learning. However, the greater the number of specimens on trial the smaller the unneutralized learning

becomes. But this has only the effect of lessening the apparent difference in the readibility of the various specimens under consideration and, hence, makes a stronger case for the order which the study shows the specimens to take with respect to readability.

The next consideration is that of the amount of reading ability with which the reader approaches the task. The ideal condition would be one in which all the readers possessed the same reading ability. This is due to the fact that the opportunities for learning are much greater in the case of poor readers than in the case of good readers. Suppose that all who read in the order 1-2-3 were poor readers and those who read in the order 3-2-1 were good readers. Then Specimen 3 would have the advantage of Specimen 1. Specimen 1 coming first in the case of the poor readers would be read very poorly, while much added reading power be developed in the reading of this material by the time Specimen 3 was reached. In the case of the good readers reading in the order 3-2-1 not nearly as much difference would be found between the reading of Specimen 3 and Specimen 1. So important was this matter that the oral reading ability of each child was thoroughly tested before the experiment was begun. The children were then divided into groups corresponding to the number of specimens to be tested. It was intended that each group have exactly the same reading power as that of any other group. As, of course, this was an impos-

sibility all the writer could do was to approach it as nearly as possible. W. S. Gray's Standardized Oral Reading Paragraphs were used to determine reading ability. The score was then placed upon a card with the child's name. The cards were then so arranged that the total scores of the various groups were as nearly alike as possible. Ordinarily the difference in the reading ability of any two groups could be made less than 2%. Even with this small difference in reading ability between the groups it would have been possible for the writer to have so assigned the groups to reading orders to so as have favored, though never so little, any given specimen. To avoid this danger the groups were assigned to their orders of reading by chance.[1]

[1] With respect to method of attack this study and that of Dr. A. R. Gilliland differ from any which preceded. All of the investigators whose work is reported in Chapter II of this study attacked the problem of determining legibility either by studying letters in isolation or by photographing the eyes while reading. It should be pointed out that letters in isolation and letters in context may differ as to legibility. While the photographing of eye movements will indicate the degree of difficulty offered by a given passage it is impossible to photograph the reading of enough material to give the work statistical validity or the child enough reading to actually test him. A stopwatch gives a quantitative measure of all the eye-movements and at the same time allows the investigator to increase the amount of reading material to such a length as will readily bring out the difference between a good and a bad variation of the reading factor under consideration.

CHAPTER III

EXPERIMENTATION

INTRODUCTION

Of the typographical factors which have a possible bearing upon the rate and quality of reading the following were subjected to experimentation: size of type, length of line, leading, and marginal regularity. For a full statement of the problems and the methods used in their solution see Chapter II, pp. 31–40.

SIZE OF TYPE

The influence of the size of the letters upon readability of type was investigated in the first four grades.

TABLE VII.—THIRD AND FOURTH GRADES

Size of Type. 100 Children—500 Readings

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
Time in Seconds Consumed in Reading					
Size of type in terms of points and height of small letters	18 points 2.75 mm.	14 points 2.00 mm.	12 points 1.75 mm.	10 points 1.50 mm.	8 points 1.25 mm.
Mean reading time in seconds	163.29	170.23	171.09	176.47	177.10
σ (dis.)	47.80	50.30	46.80	50.01	49.70
σ (mean)	2.14	2.25	2.09	2.24	2.22
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2 3.11 and 98.00	Between specimens 2 and 3 3.07 and 62.00	Between specimens 3 and 4 3.06 and 96.00	Between specimens 4 and 5 3.16 and 58.00	Between specimens 1 and 3 2.99 and 99.00
	Between specimens 1 and 4 3.10 and 99.00	Between specimens 1 and 5 3.08 and 99.00	Between specimens 2 and 4 3.18 and 99.00	Between specimens 2 and 5 3.16 and 99.00	Between specimens 3 and 5 3.05 and 98.00
Number of Errors Made in Reading					
Mean of errors	9.09	10.33	10.46	10.50	11.44
σ (dis.)	1.38	1.44	1.53	1.18	1.39
σ (mean)	.06	.06	.07	.05	.06
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2 .08 and 99.00	Between specimens 2 and 3 .09 and 93.00	Between specimens 3 and 4 .09 and 67.00	Between specimens 4 and 5 .08 and 99.00	Between specimens 1 and 3 .09 and 99.00
	Between specimens 1 and 4 .08 and 99.00	Between specimens 1 and 5 .08 and 99.00	Between specimens 2 and 4 .08 and 98.00	Between specimens 2 and 5 .08 and 99.00	Between specimens 3 and 5 .08 and 99.00

TABLE VIII.—SECOND GRADE

Size of Type. 50 Children—250 Reading

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
Time in Seconds Consumed in Reading					
Size of type in terms of points and height of small letters	24 points 3.75 mm.	18 points 2.75 mm.	14 points 2.00 mm.	12 points 1.75 mm.	10 points 1.50 mm.
Mean reading time in seconds	104.44	106.78	107.50	108.24	113.16
σ (dis.)	59.60	66.50	65.20	72.50	72.70
σ (mean)	3.77	4.21	4.12	4.59	4.60
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 4 and 5	Between specimens 1 and 3
	5.65	5.89	6.17	6.49	5.59
	65.00	55.00	55.00	77.00	71.00
	Between specimens 1 and 4	Between specimens 1 and 5	Between specimens 2 and 4	Between specimens 2 and 5	Between specimens 3 and 5
	5.93	5.95	6.22	6.23	6.18
	74.00	93.00	59.00	84.00	82.00
Number of Errors Made in Reading					
Mean of errors	5.42	5.38	5.86	5.98	6.34
σ (dis.)	2.96	3.87	4.94	4.30	4.90
σ (mean)	.19	.25	.31	.27	.31
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 4 and 5	Between specimens 1 and 3
	.31	.40	.41	.41	.36
	55.00	88.00	62.00	81.00	88.00
	Between specimens 1 and 4	Between specimens 1 and 5	Between specimens 2 and 4	Between specimens 2 and 5	Between specimens 3 and 5
	.33	.36	.37	.40	.44
	96.00	99.00	95.00	99.00	86.00

TABLE IX.—FIRST GRADE

Size of Type. 40 Children—160 Readings

	Specimen 1	Specimen 3	Specimen 2	Specimen 4
Time in Seconds Consumed in Reading				
Size of type in terms of height of small letters	30 points 4.75 mm.	24 points 3.75 mm.	18 points 2.75 mm.	14 points 2.00 mm.
Mean reading time in seconds	85.68	84.28	86.38	88.18
σ (dis.)	48.08	46.60	49.10	48.40
σ (mean)	3.80	3.68	3.88	3.83
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 1 and 3
	5.29	5.36	5.45	5.43
	60.00	65.00	63.00	55.00
	Between specimens 1 and 4	Between specimens 2 and 4		
	5.40	5.31		
	67.00	77.00		
Number of Errors Made in Reading				
Mean of errors	5.12	4.73	4.95	5.28
σ (dis.)	2.96	3.37	3.69	3.39
σ (mean)	.23	.27	.29	.27
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 1 and 3
	.35	.40	.40	.37
	86.00	71.00	80.00	68.00
	Between specimens 1 and 4	Between specimens 2 and 4		
	.35	.38		
	67.00	93.00		

INTERPRETATION OF DATA

Eighteen-point type was read with the greatest facility in the third and fourth grades. The chances that the true difference in the reading time of eighteen and fourteen-point type is greater than zero reaches the point of practical certainty. This is true also with respect to the errors made. Twelve and fourteen-point type are much alike in reading difficulty as measured by both reading time and errors. With respect to reading time the dropping from twelve to ten points of type seems to make considerable difference. The chances, however, that the difference is significant does not reach the level of practical certainty though it approaches it closely with respect to reading time. Eight point type, on the other hand, is significantly different from twelve in readability both as regards reading time and errors. Errors seem in the third and fourth grades to be the better criterion of readability as judged by the comparatively smaller σ(difi) of the means.

In the second grade twenty-four and eighteen-point type are about equally readable. Twenty-four-point type was read more rapidly but with a greater number of errors. In both rate and errors the chances of the true difference being above zero is very small being 1.5 for rate and 1.2 to 1 for errors. As in the third and fourth grades fourteen and twelve-point type show

comparative little difference in readability. As one goes to ten-point type, however, the difference becomes more significant, the chances that the true difference in readability between twelve and ten-point type being 77 in 100 for rate and 81 in 100 for errors. Whereas the chances that the true difference in readability of fourteen and twelve-point type is greater than zero are 55 to 100 for rate and 62 to 100 for errors. Since there is a continual decrease in readability as we go below eighteen-point type the chances that there is a significant difference between two different points of type increases as we increase the span between the points of type investigated. That is, for example, the chances that the true difference is above zero when considering twenty-four and ten-point type are 93 in 100 for rate and 99 in 100 for errors. In the second as in the third and fourth grades the number of errors made seem to be the better test of readability.

Twenty-four-point type seems to be the more readable in the first grade. The mean of both the rate and errors is increased as we investigate on either side of twenty-four points. The reader's attention should be called to the fact that the chances that the differences between the readability of the specimens of type investigated in the first grade are significant are small ranging from 55 in 100 to 77 in 100 for reading time and 68 in 100 to 93 in 100 for errors. The writer attributes the fact that the reliability of the scores in the first

grade is low largely to the small number of readings involved.

LENGTH OF LINE

Material was prepared so as to form six specimens of lengths 55 mm., 81 mm., 90 mm., 102 mm., 120 mm., and 142 mm. to be read by the third and fourth grades and six specimens of lengths 55 mm., 80 mm., 91 mm., 103 mm., 123 mm., and 142 mm., to be read by the first and second grades.[1] For a complete discussion of the method see Chapter II pages (31–40).

[1] Due to the failure of the press to print the material exactly according to specifications it will be observed that the line lengths studied in the third and fourth grades are not identical with those of corresponding specimens in the first and second grades. We mention this to prevent the idea that there might be a purpose in so preparing them.

TABLE X.—THIRD AND FOURTH GRADES

Length of Line. 96 Children—576 Readings

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Specimen 6
Time in Seconds Consumed in Reading						
Length of line.....	55 mm.	81 mm.	90 mm.	102 mm.	120 mm.	142 mm.
Mean reading time in seconds.	65.71	65.29	63.74	63.63	64.26	65.33
σ (dis.).....	18.30	20.20	17.19	17.70	17.70	17.90
σ (mean).....	.76	.84	.71	.74	.74	.75
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 4 and 5	Between specimens 5 and 6	Between specimens 4 and 2
	1.13	1.10	1.03	1.05	1.05	1.12
	64.00	92.00	54.00	73.00	84.00	93.00
	Between specimens 4 and 1	Between specimens 4 and 6				
	1.06	1.05				
	98.00	94.00				
Number of Errors Made in Reading						
Mean of errors....	2.99	3.07	2.94	2.86	3.24	2.91
σ (dis.).....	2.72	2.77	2.77	2.66	2.69	2.88
σ (mean).....	.11	.12	.12	.11	.11	.12
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 4 and 5	Between specimens 5 and 6	Between specimens 4 and 2
	.16	.17	.16	.16	.16	.16
	69.00	77.00	69.00	99.00	98.00	90.00
	Between specimens 4 and 1	Between specimens 4 and 6				
	.16	.16				
	79.00	62.00				

TABLE XI.—SECOND GRADE

Length of Line. 48 Children—288 Readings

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Specimen 6
	Time in Seconds Consumed in Reading					
Length of line.....	55 mm.	80 mm.	91 mm.	103 mm.	123 mm.	142 mm.
Mean reading time in seconds.	79.73	77.44	76.60	75.10	78.13	78.81
σ (dis.).....	14.20	12.20	14.00	12.90	15.60	15.10
σ (mean).....	.84	.72	.83	.76	.92	.89
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 4 and 5	Between specimens 5 and 6	Between specimens 4 and 2
	1.10	1.09	1.12	1.19	1.28	1.05
	98.00	78.00	91.00	99.00	71.00	99.00
	Between specimens 4 and 1	Between specimens 4 and 6				
	1.13	1.17				
	100.00	100.00				
	Number of Errors Made in Reading					
Mean of errors....	3.00	2.54	2.58	2.46	2.56	2.73
σ (dis.).....	2.17	1.84	2.05	1.89	1.55	2.04
σ (mean).....	.13	.11	.12	.11	.09	.12
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 4 and 5	Between specimens 5 and 6	Between specimens 4 and 2
	.17	.16	.16	.14	.15	.16
	100.00	60.00	77.00	76.00	87.00	69.00
	Between specimens 4 and 1	Between specimens 4 and 6				
	.17	.16				
	100.00	96.00				

TABLE XII.—FIRST GRADE

Length of Line. 72 Children—432 Readings

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Specimen 6
	Time in Seconds Consumed in Reading					
Length of line.....	55 mm.	80 mm.	91 mm.	103 mm.	123 mm.	142 mm.
Mean reading time in seconds.	113.76	111.14	108.50	108.22	114.75	112.02
σ (dis.).....	27.40	25.80	25.60	28.10	28.90	28.80
σ (mean).....	1.32	1.24	1.23	1.35	1.39	1.39
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 4 and 5	Between specimens 5 and 6	Between specimens 4 and 2
	1.81	1.75	1.83	1.94	1.96	1.83
	93.00	93.00	56.00	100.00	92.00	94.00
	Between specimens 4 and 1	Between specimens 4 and 6				
	1.89	1.94				
	100.00	98.00				
	Number of Errors Made in Reading					
Mean of errors....	3.01	3.25	3.00	2.82	3.35	3.25
σ (dis.).....	2.41	2.50	2.43	2.39	2.18	2.26
σ (mean).....	.12	.12	.12	.12	.10	.11
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 4 and 5	Between specimens 5 and 6	Between specimens 4 and 2
	.17	.17	.17	.16	.15	.17
	92.00	93.00	85.00	100.00	74.00	99.00
	Between specimens 4 and 1	Between specimens 4 and 6				
	.17	.18				
	86.00	99.00				

INTERPRETATION OF DATA

Reviewing the above tables in their entirety we find that they corroborate each other in placing the most desirable length of line around 102 and 103 mil-

limeters. Attention should be directed to the fact that there is, with but one exception, first grade Specimen 6, a continuous increase in the mean reading time as one recedes in either direction from the above line lengths.

The question at once arises as to what length of line the children have been accustomed to reading. In order to determine this the writer measured the line length of the books used in the first four grades of the schools in which the study was made. A study of the first grade books showed that there was no uniformity in the length of line, but that many line lengths were to be found in any book. Of the seven books examined in the second grade, one contained lines 93 millimeters in length, one 101, and five 102. Six books represented the third grade as follows: one 61 millimeters, one 81, one 96, two 102, one 103. The following lengths of line were represented in the fourth grade 94, 98, 102, 106, and 115 millimeters. Hence, except in the second grade, there is little possibility of attributing the findings of this study to previous reading habits.

Dearborn thinks favorable of a line from seventy-five to eighty-five millimeters. The results of this study do not agree with the recommendations of Dearborn. The best length of line is above 90 millimeters rather than below it in all the grades investigated. Lines that are 80 millimeters or less are clearly unfavorable.

Dearborn found that the eyes make their longest pause near the beginning of the line and a secondary

pause of more than average duration near the end of the line.[1] This is significant for the shorter the length of line, the size of the type remaining constant, the greater the number of initial and final fixations. On the other hand, as the lines become longer and longer the difficulty of making the initial fixations becomes greater. Also, lines beyond a certain length cause the reader to shift the head in order to prevent an undue amount of asymetrical accomodation. It is likely that the most desirable length of line is largely determined by the proper balance of the above factors.

LEADING[2]

Reading material was prepared so as to vary the leading only. For a complete discussion of the method see Chapter II pages (31–40).

[1] Dearborn—The Psychology of Reading.

[2] "A lead is a strip of metal used to separate lines of type. The ordinary (standard) lead is two points thick. Matter with leads between the lines is called 'leaded;' without 'solid.'" Manual of Style, The University of Chicago Press, p. 114.

TABLE XIII.—THIRD AND FOURTH GRADES
Leading. 80 Children—320 Readings

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	
	Time in Seconds Consumed in Reading				
Amount of leading in terms of points and millimeters	Solid 1 mm.	One-point 1.33 mm.	Two-point 1.66 mm.	Three-point 2.00 mm.	
Mean reading time in seconds	63.23	63.50	63.95	63.51	
σ (dis.)	25.10	25.80	22.30	22.90	
σ (mean)	1.40	1.44	1.25	1.28	
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 2 and 4	Between specimens 1 and 4
	2.00	1.91	1.79	1.93	1.90
	56.00	59.00	60.00	50.00	56.00
	Number of Errors Made in Reading				
Mean of errors	3.86	3.48	3.84	4.20	
σ (dis.)	3.38	3.40	3.35	3.25	
σ (mean)	.19	.19	.19	.18	
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 2 and 4	Between specimens 1 and 4
	.27	.27	.26	.26	.26
	92.00	91.00	92.00	100.00	90.00

TABLE XIV.—SECOND GRADE

Leading. 40 Children—160 Readings

	Specimen 1	Specimen 2	Specimen 3	Specimen 4
Time in Seconds Consumed in Reading				
Amount of leading in terms of points and millimeters	Solid 1 mm.	One-point 1.33 mm.	Two-point 1.66 mm.	Three-point 2.00 mm.
Mean reading time in seconds	92.76	90.78	92.00	94.46
σ (dis.)	57.90	59.20	53.70	56.10
σ (mean)	4.58	4.68	4.25	4.44
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 2 and 4
	6.55	6.32	6.14	6.45
	62.00	58.00	65.00	72.00
Number of Errors Made in Reading				
Mean of errors	4.70	4.08	4.12	3.96
σ (dis.)	4.23	2.82	2.72	2.56
σ (mean)	.33	.22	.22	.20
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 3 and 4	Between specimens 2 and 4
	.40	.31	.30	.30
	93.00	55.00	70.00	65.00

TABLE XV.—FIRST GRADE

Leading. 36 Children—108 Readings

	Specimen 1	Specimen 2	Specimen 3
Time in Seconds Consumed in Reading			
Amount of leading in terms of points and millimeters	Solid .50	Four-point 1.80	Ten-point 3.80
Mean reading time in seconds	66.00	65.61	62.83
σ (dis.)	35.60	33.90	34.20
σ (mean)	3.43	3.26	3.29
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 1 and 3
	4.73	4.63	4.75
	54.00	73.00	74.00
Number of Errors Made in Reading			
Mean of errors	3.08	3.44	3.10
σ (dis.)	2.54	2.23	2.19
σ (mean)	.24	.21	.21
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 1 and 3
	.32	.30	.32
	87.00	87.00	52.00

INTERPRETATION OF DATA

The table for the third and fourth grades shows that in this experiment two millimeters of leading,[1] or space

[1] By the term *leading* is meant the amount of space between any two consecutive lines as measured by the vertical distance between the base of a descender, as the letter (p) in an upper line and the top of an ascender, as the letter (d) in the line below. The term *leading* comes from the custom of separating the type bodies of one line from those of the next by means of strips of lead. See p. 32 for further description.

between the lines, have no advantage over solid matter or, in this case, one millimeter of leading.[1] Considering errors alone 1.33 millimeters of leading is best. Since the chances of a significant difference between the mean of the error represented in Specimen 2 and the other specimens are all above 90 and since the number of errors made seem to be the more valid criterion of reading difficulty it is tempting, in spite of the fact that the difference in reading times are insignificant, to conclude that 1.33 millimeters of leading is most satisfactory in these grades. Considering the study as a whole the only conclusion that can be made is that there seems to be no justification for more than 1.33 millimeters of leading in the third and fourth grades.

We can conclude nothing from Table XIV as to the merits of various amounts of leading in the second grade. As to why the reading time should favor one-point and the errors three-point leading the writer is at a loss to explain. One would expect the time consumed to be a function of the errors made. However, there is some evidence that a pupil in reading difficult material will tend to keep his normal rate of reading at the expense of errors.

[1] Due to the fact that the space between the lines in any two specimens of solid matter may not be equal (the size of the type body on which the letter is supported varies with the specimen of type thus causing the amount of space between lines often to differ with different styles of type when the same number of lead points are used) the term *millimeters of leading* is preferable to the term *points of leading* and is used by all investigators in the hygiene of reading.

The results of the study of leading in the first grade as shown by Table XV are equally confusing. The writer overestimating the significance of reading time concluded in an article on this study published in School and Society Vol. XVII that 3.80 points of leading were desirable in the first grade. A further statistical treatment of the data reveal the fact that errors made are even more significant than reading rate. Hence, we can conclude nothing from Table XV.

The results of this study of leading are inconclusive. There is a faint suggestion that at least 3.80 millimeters of leading is desirable in the first grade. There is however, no evidence that leading greater than 1.33 millimeters has any advantage in the second, third, and fourth grades.

REGULARITY OF LINE MARGINS

The study of line margins is limited to the first grade. This is largely due to the fact that this is the only grade in which there is a difference in books with respect to this factor. Three specimens of material were prepared with margins as follows: No. 1—both margins regular, No. 2—left margin regular, right irregular, and No. 3—both margins irregular. For a complete discussion of the method see Chapter II pages (31–40).

TABLE XVI.—FIRST GRADE

Margin. 36 Children—108 Readings

	Specimen 1	Specimen 2	Specimen 3
Time in Seconds Consumed in Reading			
Amount of leading in terms of points and millimeters	Both margins regular	Right margin irregular; left regular	Both margins irregular
Mean reading time in seconds	50.25	49.69	48.50
σ (dis.)	20.50	27.50	25.70
σ (mean)	1.97	2.65	2.47
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 1 and 3
	3.30	3.63	3.16
	57.00	63.00	71.00
Number of Errors Made in Reading			
Mean of errors	2.25	2.44	1.78
σ (dis.)	1.69	2.24	1.88
σ (mean)	.16	.22	.18
σ (diff.) and chances in 100 that difference is significant	Between specimens 1 and 2	Between specimens 2 and 3	Between specimens 1 and 3
	.27	.30	.24
	76.00	99.00	98.00

INTERPRETATION OF DATA

The above table clearly indicates that Specimen 3 in which both margins are irregular is the best. Specimen 2, however, in which only the right margin is irregular has no advantage over Specimen 1, in which both margins are regular. This means that the advan-

tage of irregularity lies with the margin to the left of the reader. The first grade child has not yet mastered the difficulties involved in changing from the end of one line to the beginning of the next. Irregularity of the left margin has this advantage, it makes the beginning of the following line easier to find. The question still remains as to whether or not the best reading habits cannot be most readily and effectively attained by using a solid left margin from the first regardless of the initial difficulty offered by it. There is nothing to be gained by making the right margin irregular and much paper could be saved by making it full.

CHAPTER IV

SUMMARY OF CONCLUSIONS

Size of Type:

Eighteen-point type (height of small letters 2.75 mm.) is more readable in all the first four grades than type which is smaller. Twenty-four-point type offers about the same reading difficulty in the second grade as does eighteen-point type. In the first grade twenty-four-point type is more readable than that which is smaller or larger. The question of its use in this grade should be one of expense rather than desirability.

Length of Line:

The most desirable length of line for the first four grades lies around 100 millimeters.

Leading:

There is no justification for more than 1.33 millimeters of leading in the third and fourth grades. The studies in the first and second grades are inconclusive.

Margin:

There is no advantage to be gained in the first grade in making the right margin (margin on reader's right) irregular. There is an advantage to be gained in making the left margin irregular.

The following table gives a summation of the recommendations made on the basis of this study:

Grade	Age	Size of type in terms of points of type and height of small letters	Length of line	Leading in terms of points and space between the lines	Margin
First	6 yrs.	18-point (Min.) 24-point (Max.) or 2.75 mm. (Min.) 3.75 mm. (Max.)	95 to 105 mm.	Inconclusive	Left margin irregular; right margin regular
Second	7 yrs.	18-point (Min.) 24-point (Max.) or 2.75 mm. (Min.) 3.75 mm. (Max.)	95 to 105 mm.	Inconclusive	
Third and Fourth	8 yrs. 9 yrs.	18-point or 2.75 mm.	95 to 105 mm.	Approximately 1.33 mm.	

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